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MICROSCOPIC REPLACEMENT VERSUS INJECTION IN ORES

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Much emphasis recently has been placed on the relative importance of replacement and injection in ore deposition. As a phase of this discussion much attention has been paid to included fragments in veins. Microscopic examination of ores reveals much information on these processes. Until the publication of the "Ore Magmas"¹ many of the mineral relationships observed microscopically were attributed, and rightly so, it is believed, to replacement. There has been a growing tendency since then to interpret a later mineral as injected in the earlier, or as having consolidated from a more or less stationary ore magma.² It seems worth while, therefore, to present some of the microscopic evidences of replacement or of possible injection. This does not necessarily mean that the process observed microscopically was the dominant one on a large scale, but it is at least strongly indicated.

The evidence presented here has been accumulated incidentally to a microscopic study of ores for several years and without the specific problem in mind. Thousands of specimens have been examined and some of the examples presented might be multiplied several times. The specimens illustrated are in the Mineralogical Laboratory of the Department of Geology at the University of Minnesota. The criteria for processes active in ores as deduced from microscopic study have not been thoroughly worked out, but the textures due to the replacement or corrosion of preexisting minerals by a later mineral in primary ores may be recognized by comparison with the results of similar processes in the oxidation and secondary (supergene) enrichment of ores. It is assumed that no one would question the replacement relation when an oxidized mineral replaces a primary mineral of the same

¹ Spurr, J. E.: The ore magmas. McGraw-Hill Book Co., New York.

² See, for example, L. S. Ropes; *Eng. and Min. Jour.*, vol. 122, 899 (1926).

metal. The same is true of a secondary enrichment, with the fact acknowledged that it is not always possible to recognize supergene replacement without field evidence.

As examples of structures produced by the alteration to, or replacement of, ore minerals by oxidized minerals Figures 1, 2 and 3 are presented.

Figure 1 shows pyrite partly altered to limonite and the rounded, corroded nature of the pyrite particularly is to be noted. This structure is characteristic of ores in which one mineral has practically replaced another, especially when the replaced mineral is without cleavage or parting, as is usually the case with pyrite.

Figure 2 shows chalcocite partially altered to malachite. It is quite obvious that the fragments could not be fitted together although they are somewhat angular. Figure 3 shows a similar case of alteration of galena to cerussite with the alteration controlled by the cleavage. This structure might be mistaken for one showing a second vein filling, but the control by cleavage, as well as the nature of the alteration, shows this to be a replacement. The characteristics of these structures are of value for comparison with cases whose origin is more uncertain.

Figures 4, 5, 6, 7 and 8 represent replacement structures of both secondary (supergene) and primary (hypogene) origin.

Figure 4 is a micrograph of rich chalcocite ore from the Old Dominion mine, Globe, Arizona. In the chalcocite are rounded fragments of pyrite grouped in a manner plainly indicating that the pyrite fragments are the remains of a large grain now extensively replaced by chalcocite. This has been termed "ice cake" structure. The essential difference between the ore of Figure 1 and that of Figure 4 is that oxygen has been introduced and sulphur extracted in the first, and copper has been introduced and iron extracted in the second. In each case a new mineral has partially replaced the original mineral.

Figure 5, also from Globe, shows chalcocite largely replaced by a network of quartz. It is noteworthy that the chalcocite remnants are much less rounded than the pyrite fragments of Figures 1 and 4, and in this respect the texture is similar to that shown by Figure 2. It seems obvious that the structure of the replaced mineral exerts a strong control on the shape of the residual fragments. It is evident that the fragments of Figure 5 could not be fitted together and therefore corrosion has been active. Dr.

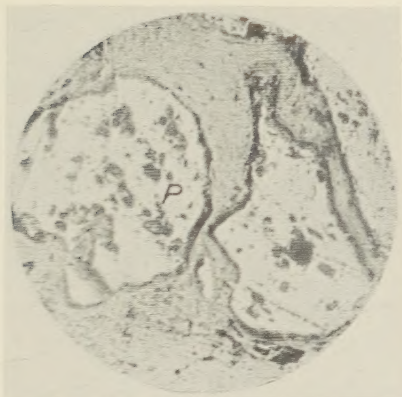


Figure 1. Rounded fragments of pyrite (P) partially altered to limonite, 9th level, Old Dominion mine, Globe, Arizona. Mag. 52X

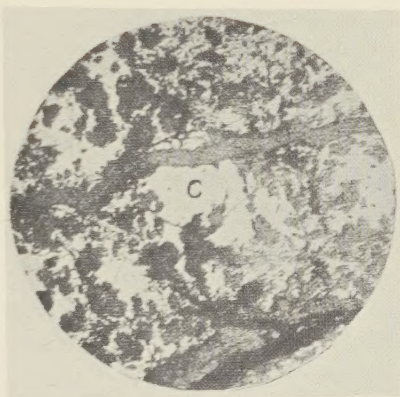


Figure 2. Irregular fragments of chalcocite (C) largely altered to malachite (dark), 6th level, Old Dominion Mine, Globe, Arizona. Mag. 30X

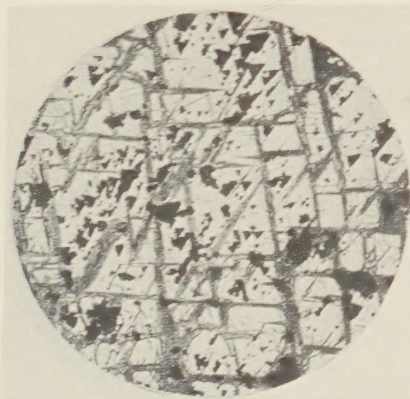


Figure 3. Galena partially altered to cerussite developed mainly along cleavage planes. Kent Mine, Bannack District, Montana. Mag. 62X.

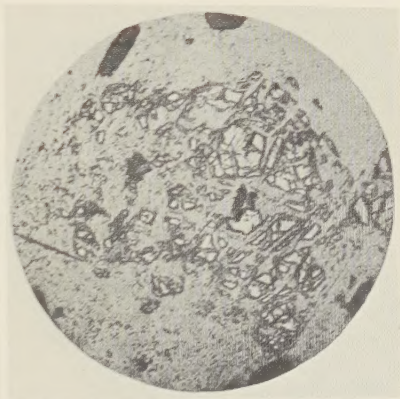


Figure 4. Rounded fragments of pyrite grain partially replaced by chalcocite. 14th level, Old Dominion mine, Globe, Arizona. Mag. 72X.

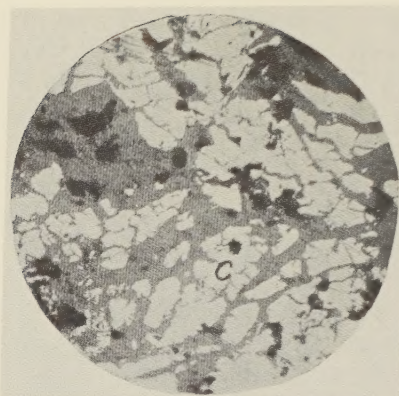


Figure 5. Irregular fragments of chalcocite (C) in quartz. Replacement shown by rough and rounded form of chalcocite. 14th level, Old Dominion mine, Globe, Arizona. Mag. 56X.

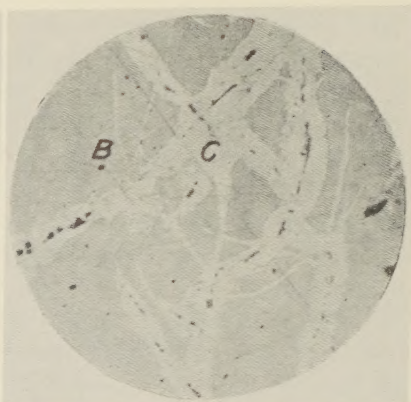


Figure 6. Bornite (B) cut by veinlets of chalcocite (C). An early stage of replacement doubtless supergene. 15th level Old Dominion mine, Globe, Arizona. Mag. 56X.

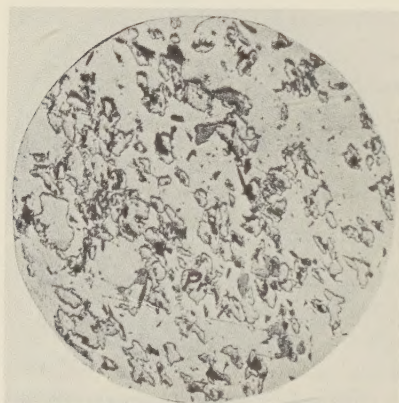


Figure 7. Rounded fragments of pyrrhotite (Pr) in galena. A primary ore showing replacement. Sullivan mine, Kimberley, B. C. Mag. 33X.

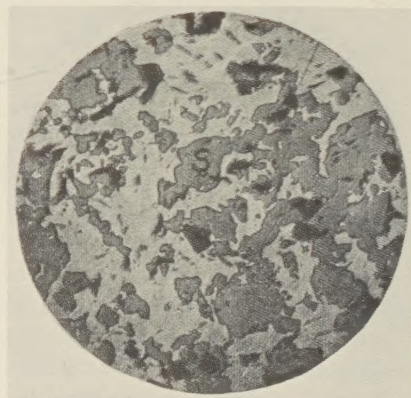


Figure 8. Irregular to rounded fragments of sphalerite (S) in galena. Not as far advanced as Figure 7. Sullivan mine. Mag. 36X.

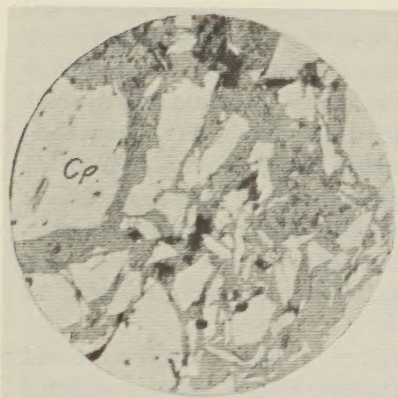


Figure 9. Chalcopyrite (Cp) as angular fragments in a quartz-hematite matrix. No corrosion by later material. Iron Cap mine, Globe, Arizona. Mag. 40X.

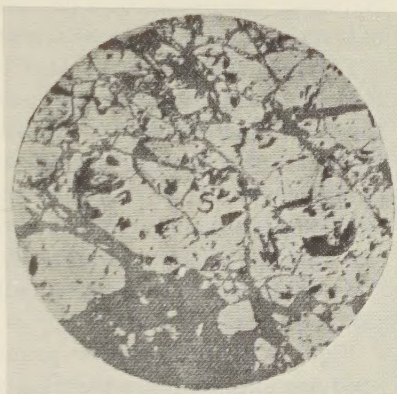


Figure 10. Angular fragments of sphalerite in quartz. Little evidence of replacement by later quartz. Butte and Superior mine, Butte, Mont. Mag. 72X.



Figure 11. Angular fragments of arsenopyrite in quartz with but slight corrosion. Stannite-wolframite ore, East Pool mine, Cornwall, England. Mag. 36X.



Figure 12. Micrograph of a thin section of a sulphide diabase. Note fresh olivine (O), augite (A) and plagioclase (P). Euhedral feldspar crystals are embedded in sulphides (black). Exploration pit, Cook County, Minnesota. Mag. 16X.

Bateman³ has presented a discussion of angular inclusions which is of interest in connection with some of the figures of this type.

Figure 6 shows an incipient state of replacement where chalcocite, presumably supergene, is replacing bornite. The bornite fragments are angular and to some extent can be fitted together, but a study of a larger field reveals a far from complete fit at many places. It is known in the case of supergene replacement that the alteration is performed by slowly percolating waters, thus allowing the removal of material not needed in the new minerals. This alteration characteristically follows fractures existing in the ore.

Figures 7 and 8 are from primary ores of the Sullivan mine and are reproduced from a previous article.⁴ Figure 7 shows rounded residual fragments of pyrrhotite in galena and Figure 8 shows similar fragments of sphalerite in galena. The resemblance of Figure 7 to Figure 4 is obvious. The sphalerite of Figure 8 is not as much corroded as the pyrrhotite of Figure 7, but the process is evident. Whether the galena was brought in by dilute solutions or injected as an ore magma, there has been considerable corrosion of the preexisting minerals. Inasmuch as dilute solutions would more easily carry away the material such evidence is usually taken to indicate the activity of solutions in the deposition of ore. The analogy between these textures and the texture of oxidized and secondarily enriched ores is striking.

Examples of possible injection of minerals into preexisting minerals without replacement are by no means as common as the type described above. No good example is at hand of the ore mineral acting as a matrix in brecciated preexisting ore minerals. The cases cited show brecciation of ores and later injection of quartz.

Figure 9 was taken from a primary ore from the Iron Cap mine, Globe, Arizona. Chalcopyrite has been shattered and the angular fragments are scattered in a matrix of quartz and hematite. This structure has been called "exploding bomb" structure by Graton and Murdock.⁵ There has been no corrosion of the fragments by

³ Bateman, A. M.; Angular inclusions and replacement deposits: *Econ. Geol.*, vol. 19, 504-520 (1924).

⁴ Schwartz, G. M.; Microscopic character of ores from the Sullivan mine, Kimberley, B. C.: *Eng. and Min. Jour.*, vol. 122, 375-377 (1926).

⁵ Graton and Murdock; The sulphide ores of copper: *Trans. Am. Inst. Min. Eng.*, vol. 45, 29-93 (1913).

the quartz-hematite solution. An examination of this type of ore at higher magnification shows numerous small crystals of hematite in the quartz and these are more or less oriented as in the trachytic texture of petrology. The hematite gives an undeniable impression of having been oriented by the flowing of the materials around the chalcopyrite fragments. The chalcopyrite, however, shows no evidence of orientation as might be expected, and one is left somewhat in doubt as to the interpretation. A mixture of quartz and specular hematite suggests a moderate or high temperature of formation. The series of specimens of this type are the best indication found microscopically of injection of a viscous material such as the ore magma.

Figure 10 shows a case of quartz cementing a microscopic breccia of sphalerite. There has obviously been little if any corrosion, by the entering quartz solution.

Figure 11 shows a case somewhat similar to Figure 10. Arsenopyrite fragments are cemented by quartz with no apparent corrosion. The ore is from the Cornwall tin deposits.

Figure 12 is a micrograph of a thin section of a sulphide rock previously described by the writer.⁶ The rock is composed of fresh olivine, augite, plagioclase, and sulphides (pyrrhotite and chalcopyrite). Euhedral crystals of plagioclase are embedded in the sulphides with no evidence of replacement or later introduction of any sort. This is interpreted as a case of ore minerals crystallizing as part of the rock, apparently an uncommon phenomenon, even in magmatic segregation deposits.⁷ Dr. Emmons⁸ has described two practically identical cases. Both apparently represent sulphides as original constituents of a granite. At one place galena encloses euhedral feldspar and at another molybdenite plays the same role.

Textures which indicate the more or less simultaneous development of two or more minerals have been omitted. There are several textures which indicate that relation, but they do not reveal, in most cases, the manner of introduction of the ores. Textures of that type might well deserve a separate discussion.

⁶ Schwartz, G. M.; A sulphide diabase from Cook County, Minnesota: *Econ. Geol.*, vol. 20, 261-265 (1925).

⁷ Tolman and Rogers; Magmatic sulfid ores: *Pub. Leland Stanford Junior University*.

⁸ Emmons, W. H.; Some ore deposits in Maine, and the Milan mine, New Hampshire: *U. S. Geol. Survey Bull.* 432, pp. 34 and 42, and Plates I and III (1910).

Emphasis has been placed on angularity as contrasted with rounded fragments. Dr. Bateman⁹ has presented evidence showing that fragments microscopically and in hand specimen may retain their angularity during replacement. This is to some extent shown in Figures 3, 4 and 6, and adds emphasis to Dr. Bateman's conclusions which are stated as follows. "The evidence drawn on above, though by no means all that exists, is sufficient to illustrate without further burden to the reader, that angular fragments exist as inclusions—and unsupported ones—in deposits that are considered to have been formed by replacement."

There is, however, an obvious difference between the angularity of Figure 4 and that of Figure 9; in the former replacement is obvious and in the latter the manner in which the fragments fit precludes replacement. It is obvious from Dr. Bateman's discussion that too much reliance must not be placed on one type of texture and the writer does not consider the criteria illustrated here as rigid tests of one or another type of origin. They are presented to show the kind of evidence which may be utilized in microscopic work to indicate the activity of certain processes. The criteria must be used with judgment and in conjunction with all available evidence of field and laboratory. Everyone admits the inadvisability of neglecting field evidence in favor of microscopic work, and it is practically as unwise to neglect microscopic study in favor of field evidence.

It is noteworthy that examples of replacement and of angular unreplaced fragments may be taken from the same deposit. Replacement may, of course, take place to some extent in an ore magma as stated by Mr. Spurr, and therefore microscopic evidence of replacement does not necessarily preclude formation from an ore magma. It is true, however, that replacement occupies a much more important place in the conception of ores being deposited by dilute solutions than by the much more concentrated ore magma. Microscopic study leads one to favor the older conception as indicated especially by the work of Lindgren, Graton, Emmons, Bateman, and others. The more in detail the ores are studied, the more convincing is the evidence of replacement as an important process in most epigenetic ore deposits. In this connection it may be well to emphasize that ores do not commonly show textures similar to those found in igneous rocks. There is normally a clear sequence of introduction although two minerals may be apparently of the same age in some ores.

⁹ *Op. cit.*

THE HIDDENITE OCCURRENCE IN
NORTH CAROLINAS. C. DAVIDSON, *Harvard University.*

The first discovery of hiddenite was made in 1879 near Stony Point, Alexander County, N. C. Specimens of this emerald green gem mineral, peculiar to North Carolina, were sent by Mr. W. E. Hidden to Dr. J. Lawrence Smith of Louisville, Kentucky, who determined the mineral as spodumene, and gave this variety the name hiddenite in honor of the discoverer.

The property, from which these so-called lithia emeralds were mined, was worked intermittently for some years, and a number of specimens found their way into various mineralogical collections. During the last few months the mine has again been opened up by Mr. W. B. Colburn of Statesville, N. C., who, up to the present, has recovered a large number of museum specimens of hiddenite, together with a number which should cut into beautiful emerald green gems of small size.

Professor Charles Palache of Harvard University and the writer were able, through the kindness of Mr. Colburn, to pay a short visit to the property and collect a suite of typical specimens which will form the basis for a full mineralogical description. The following brief account of the general occurrence may however be of interest, as there are no adequate published descriptions of the deposit.¹

The Hiddenite mine, as mentioned previously, is situated in Alexander County in the Piedmont belt of North Carolina, about fifteen miles northwest of the town of Statesville. It can be easily reached by automobile from Statesville as its exact location is about one mile beyond Hiddenite postoffice, and about one hundred yards from the main highway between Statesville and Taylorsville.

The red lateritic soil, which represents an almost universal cover of the bedrock in this region, has been stripped off by the open-cut mine work, over an irregular area twenty to fifty feet wide by approximately one hundred and fifty feet long. Where exposed by the open-cut the laterite is from ten to fifteen feet

¹ In *U.S.G.S. Bulletin* 74, Minerals of North Carolina, by F. A. Genth there is a complete list of the minerals found at the Hiddenite Mine.

deep with an astonishingly sharp transition into apparently fresh unweathered bedrock. The open cut has been carried to a maximum depth of about twenty feet in the unaltered rock, which consists of a fine-grained quartz-biotite-garnet gneiss. This gneiss, which probably represents a completely recrystallized argillaceous quartzite of Pre-cambrian age, has been greatly folded, resulting in intense crumpling and contortion. Prior to or during this folding, the gneiss was invaded by solutions, which resulted in the development of numerous lenticular quartz-feldspar pegmatites. These range from paper-thin veins to dikes upwards of a foot in width, and in numerous places the large feldspar individuals are granulated and drawn out into "augen" shapes by the folding. Apparently later than this first lit-par-lit injection were two periods of more complex mineralization, both of which gave rise to the formation of hiddenite. The first of these periods resulted in a number of narrow pegmatites which contain hiddenite crystals in small druses associated with quartz, feldspar, pink mangiferous garnet, biotite, calcite, green chromiferous muscovite, and small crystals of pyrite, rutile, black tourmaline and beryl. This type of pegmatite, or one closely allied to it, also contains hiddenite as hypidiomorphic crystals within the pegmatite itself and not confined to the druses. A characteristic feature of these dikes is an abundance of biotite at the contacts with the enclosing wall rocks.

The hiddenite deposited during this period is twinned on *a* (100), elongated parallel to the *c* axis, and while somewhat tabular parallel to the front pinacoid, shows pronounced development of prismatic forms.

Up to the time of our visit most of the gem material had been obtained from a single large druse, which was found in a dike of this type. Specimens from the wall rock of this druse contained a considerable amount of a peculiar blue lithia-bearing amphibole of the nature of holmquistite.

Following this first hiddenite mineralization a series of shear planes were developed which locally form the site of druses containing hiddenite crystals of two habits. These habits are respectively—thin plates parallel to the front pinacoid with square or rectangular outline; and rather thick tables, shortest in the direction of the vertical axis and with a peculiar deep grooving on the

tabular surface. Because of their twinning these crystals appear strikingly orthorhombic in form.

Associated with these hiddenite crystals are beautiful crystal-line developments of dolomite, siderite, quartz, biotite, a complexly twinned mineral which appears to be adularia, pyrite and delicate rutile crystals. The most striking feature of these druses is the manner in which the crystals are implanted on the bare walls of the fissure, without any apparent alteration of the wall rock.

In both types of occurrence solution of the hiddenite crystals has been locally active resulting in partial destruction of the crystals. A number of pseudomorphs of colorless mica after hiddenite were found, and in many places the hiddenite crystals are coated with what appears to be minute scales of chlorite, hitherto called *hisingerite*. (*cf. U.S.G.S. Bulletin 74*).

The very complex structural history of the rocks containing the deposit, together with the several periods of mineralization, make it difficult to give a concise outline of the series of events which took place during its formation. For this reason, coupled with the shortness of our visit to the property, no speculations as to the source and character of the mineral-bearing solutions will be considered in this short paper.

THE GRANITE OF CONWAY, NEW HAMPSHIRE, AND ITS DRUSE MINERALS

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STATEMENT OF THE PROBLEM

A vertical sheet, in the plane of which numerous miarolytic cavities or druses occur was found in a New Hampshire granite quarry. This quarry, known as the "Redstone Red," is located in Conway Township at Redstone Station, Carroll County. The minerals of these druses offer considerable interest in themselves and a description of their more important features forms a part of this paper. Several of these minerals, however, occur as deuteric minerals in the body of the igneous rock away from this vertical sheet. These deuteric minerals and their probable contemporaneity with the minerals in the druses furnish a very interesting study in the problem of post-consolidation mineral formation.

LOCATION OF THE GRANITE AND ITS GENERAL FEATURES

The granite underlies an area about 25 by 35 miles in extent, mostly in Carroll County, east-central New Hampshire. It has been described by Hitchcock,¹ Villarella,² Perry,³ and Dale.⁴ Mr. M. K. Billings of Harvard University has recently prepared a thesis for the doctorate dealing with the geology of an area which includes some of this granite.

Although it is a member of the series called by Hitchcock the Pemigewasset series, the granite, which is of post-Devonian age, has not been named. The name Conway used to designate it by Hitchcock has been assigned by the U. S. Geological Survey to an important schist of the vicinity.

The "Redstone Red" quarry is located in the hill side which is the south end of a series of summits known as Black Cap, Middle Mountain and Rattlesnake Mountain. These hills are shown on the North Conway topographic sheet published by the U. S. Geological Survey. About 800 feet west of the "Redstone Red" quarry is the "Redstone Green" which has been opened in a more alkaline granite, probably a separate intrusion, and one in which no druse or pegmatite minerals were found.

The granite of which that at the "Redstone Red" quarry is typical is described by Dale⁵ as a reddish to greyish white biotite granite of coarse grain without foliation or granulation. The mineral constituents in the order of their abundance are: perthitic feldspar, amethystine and smoky quartz, some separate oligoclase-albite, biotite (and in places hornblende), and with the following accessory minerals; ilmenite, apatite, fluorite and allanite.

An estimate of the average mineral composition based on Rosiwal measurements by Dale is as follows:

Feldspar.....	63.15%
Quartz.....	31.04%
Mica.....	5.81%

¹ Hitchcock, C. H.; The geology of New Hampshire, vol. II, pp. 142-143 (1877).

² Villarella, Juan d.; Los granitos de las canteras "Leahy," "Redstone," and "Bienvenue," Estados Unidos: *Bol. Soc. Geologica, Mexicana*, Tomo VI, pp. 49-53 (1907).

³ Perry, J. H.; Notes on the geology of Mt. Kearsage, New Hampshire: *Jour. Geology*, vol. 11, pp. 403-410 (1903).

⁴ Dale, T. N.; The commercial granites of New England: *U. S. Geol. Survey Bull.* 738, pp. 166-168 (1923).

⁵ *Op. cit.*, p. 166.

THE DRUSES IN THE GRANITE

The quarry was visited by the writer in 1921 and again in 1926. He also studied material collected by Professor Charles Palache in 1918. In October, 1926, all of the druses to be seen in place in the quarry were confined to a single vertical sheet, striking N. 52° W.; the granite throughout the quarry being otherwise free from them. This sheet was at that time the north face of the quarry in its western part. In the eastern part the work had not been carried far enough north to reach the sheet. In thickness the sheet probably averages about a foot. Since a joint had opened parallel to it a large section of its face is open to view in the quarry wall. The sheet is in the nature of a pegmatite dike since it differs in mineralogical composition and texture from the normal phase of the granite, and consists dominantly of pink microcline feldspar, some of the crystals of which are large, disseminated biotite and random large crystals of allanite and ilmenite. Quartz, though not uniformly distributed, occurs locally in large crystals or as big masses. Themiarolytic cavities, which have been simply spoken of above as druses, are of two kinds. Small ones are in places closely spaced. Elsewhere occur larger open cavities, the diameters of which reach 18 inches.

The larger cavities show in section a wall of biotite with microcline, then a zone of graphic granite which is finer grained on the wall side and coarser toward the open side. Zircon and allanite grains were found in a few instances in the graphic granite zone. There is, then, a lining of large euhedral and sub-hedral grains of pink feldspar and quartz which project into the cavity. These grains are in turn coated with small crystals of later minerals.

The larger cavities have thus a distinctly banded structure.

The smaller cavities lack this banded structure and appear rather as haphazard vugs due to selective solution of the microcline. They commonly contain only a few mineral species; albite, and biotite or chlorite being present in most, although fluorite is present in a very large number of them.

The larger cavities with the banded structure are considered to have been formed by entrapped gas in the pegmatite magma, but later entered by a succession of solutions bringing in new material. The smaller ones are due to the partial solution of the

solid pegmatite. Koenigsberger⁶ found these same two types of cavities in the Alpine granites. He stated that strongly compressed gas formed, during the time before the liquid magma was entirely solid, spherical or ellipsoidal cavities which he called "druses." These cavities are lined with minerals which were still crystallizing out of the granite. Then with progressive cooling of the magmatic waters, the pyrogenetic minerals of the granite were destroyed and cavities called "Kluften" (clefts) were made by

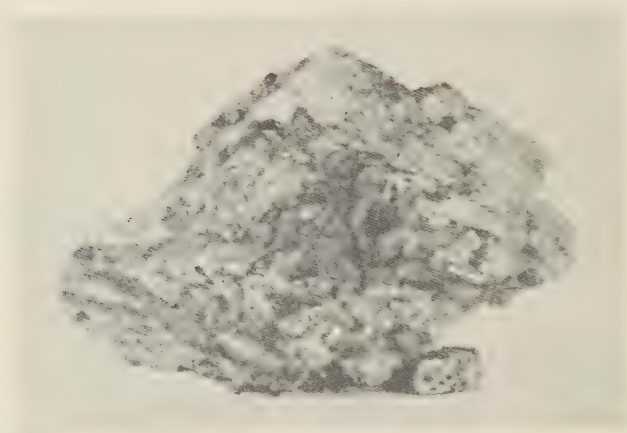


FIG. 1

Photograph of a druse showing lining of quartz and feldspar. 1/6 natural size.

solution and in which adularia, albite, epidote, quartz, fluorite, apatite, calcite, chlorite and zeolites formed.

These terms "druses" and "clefts" thus defined by Koenigsberger are here used with the meanings given to them by him. Figure 1 illustrates a druse, and Figure 2 is a photograph of a specimen containing many closely spaced clefts.

In this "Redstone Red" quarry there are many vugs which seem to have formed partly as druses, and to have been enlarged by the later solutions. Such vugs contain small crystals of microcline and quartz, with later albite, fluorite, chlorite, etc.

⁶ Koenigsberger, J.; *Die Minerallagerstätten im Biotitprotgein des Aarmassivs: Neues Jahrb. f. Mineral. etc., Beilage Band*, vol. 14, pp. 117-118 (1901).

Landes⁷ believes that most of the pockets in the pegmatites of Central Maine are secondary in nature.

The paragenesis of the minerals in the druses and clefts indicates the following succession of events, a succession which may be divided for convenience into stages, although the stages probably overlapped without a break between any two:

1. An early formation of a pink microcline and a biotite of high mean refractive index, from a "pegmatite magma," that is, a

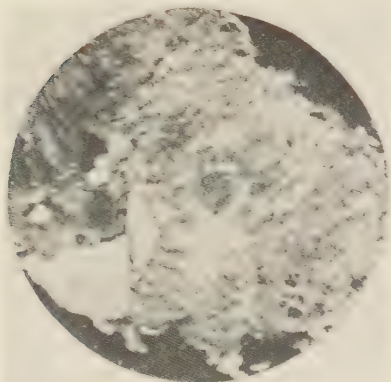


FIG. 2

Photomicrograph of a portion of a thin section of the granite showing intense albitization of the microcline. The white is albite, the grey microcline. Crossed nicols 30X.

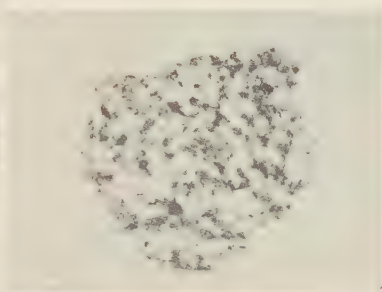


FIG. 3

Photograph of specimen containing many small clefts, lined with chlorite and albite crystals. $\frac{1}{4}$ natural size.

magma rich in volatile constituents. The trapping of these volatile constituents formed (but did not fill) the larger cavities. Emanations continued to rise through the now formed pegmatite dike and began to fill the cavities with microcline and quartz and with a few other minerals,—ilmenite, zircon and allanite. The high index biotite no longer formed.

The first stage may be called the microcline stage.

2. A period of solution and albitization during which some of the microcline was dissolved, and if a void was left, a coating of glassy albite crystals was formed in parallel growth on the parent microcline surface, or the void was filled volume by volume by massive

⁷ Landes, K. K.; The paragenesis of the granite pegmatites of Central Maine: *Amer. Mineral.*, vol. 10, p. 364 (1925).

albite. These examples of albitization are very striking as they are also in so many of the New Hampshire and Maine pegmatites and as recently described by Schaller⁸ in the California pegmatites.

This second stage was the time of formation of the small clefts as is fixed by the absence from them of microcline and quartz crystals, but the presence in them of albite and later minerals.

3. A period of formation of several minerals, the most important of which in quantity were fluorite and chlorite. The relative time of formation of the several minerals can not be fixed since only a few were ever found together. The minerals belonging to this stage are a green biotite of moderate refractive index, occurring in rosettes of tiny flakes; minute crystals of octahedrite and brookite, in one instance definitely and probably always as pseudomorphs of ilmenite; fluorite and fluor-apatite; several chlorite minerals of varying properties and several sulphides found in very minor amounts (pyrite, arsenopyrite, galena and sphalerite).

4. A stage of carbonate formation, closing the sequence of minerals of magmatic origin. Siderite formed first, followed by calcite which is found in a variety of habits. A green chlorite mineral of low mean refractive index formed contemporaneously with the carbonates.

Long after these four stages of mineral formation which had closely followed the intrusion of the granite, and represented the effects of its abyssal crystallization and cooling, another period began when the erosion surface was brought down near its present position and groundwater began to circulate through the granite and into the druses and cavities. Hematite and limonite formed as did a variety of nontronite which filled many of the smaller vugs with a light yellow powder.

INTERESTING FEATURES OF THE MINERALOGY OF THE DRUSES

The minerals of the clefts and druses made a fascinating study. Some of their most interesting and striking features will be enumerated.

1. Some of the quartz is very attractive in appearance due to its jet black color. Colorless, smoky and milky varieties of quartz occur. Many of the crystals are zoned, with colorless interiors and smoky exteriors. The crystallography of the grains is usually

⁸ Schaller, W. T.; Genesis of lithium pegmatites: *Amer. Jour. Science*, (5) vol. X, pp. 278-279 (1925).

simple, for only the prism and the terminating rhombohedrons "r" and "z" occur on most of them. On a few the faces "x" and "s" were also observed. The "m" face is deeply striated on the majority of the crystals, and a tapering form due to the frequent alternation of the prism and the rhombohedron is the characteristic shape.

2. The microcline is red-brown, to pink in color. Crystals as large as 10 inches in diameter were seen in the quarry, although the majority of them are smaller. Many crystals exhibit a pretty schiller on the murchisonite parting. Only the common crystal faces "m," "z," "b," "c," "x," and "y" are represented on most of the crystals although a few were noted on which the "n" face was developed. One Mannebach twin was found, while Baveno twins are not rare among the crystals.

3. The crystals of albite are very interesting because of the remarkable uniformity with which they grew in parallelism with the parent microcline grain. This was illustrated especially well by the albite crystals found growing to the surface of a Baveno twin of microcline. On the adjacent (010) faces of the twin (across the twin plane) the tiny albite crystals which are tabular parallel to their *a* and *c* axes lie flat on their (010) faces. On the two adjacent (001) faces of the Baveno twin of microcline the tabular albite crystals stand erect on their (001) faces. On the microcline twin the Baveno twin line is offset slightly in one place, so that the (010) face and the (001) face are together in the same plane. On one side of the offset twin line the little tabular albite crystals perched on the microcline face stand erect on their (001) faces, while on the other side of the line they lie flat on their (010) faces.

4. Zircon occurs in very small crystals, consisting of the pyramid, with only a suggestion of the prism.

5. The chlorite is of interest because of the variety of species represented in the druses and clefts. Plates of strigovite with an average refractive index of 1.660 occur in some, while curved worm-like books of pro-chlorite of a mean refractive index of 1.630 were found in others. Tiny green flakes of penninite were found interlaminated with tabular crystals of calcite, and coating crystals of quartz and feldspar.

6. Apatite, although of rare occurrence, is represented in a few clefts by gem quality crystals. On one, the following faces

were identified on the goniometer: "c," "x," "y," "R," "n," "s," "m" and "mu."

7. The abundance of the fluorite attracts immediate attention upon studying the clefts and druses. Along the face of the quarry opened in the plane of the sheet, hundreds of small clefts are visible. Many of these contain a single crystal of fluorite one-eighth to one-third as large as the cleft. Some of the crystals have an unusual form. Such had begun to grow as a simple cube, modified slightly by the octahedron, but later a new and smaller cube began to grow on each exposed larger cube face. Now, each cube face has a smaller cube perched upon it. In color the fluorite varies from purple to colorless.

8. The calcite is attractive because of the variations in its habit. Drusy coatings of dog-tooth spar represent one habit; rosettes of small flat plates are a second, while larger pearly plates fill cavities two to three inches in diameter. It is with this platy calcite that the penninite is intergrown.

9. Pseudomorphs occur in many of the clefts and druses and add appreciably to the interest of their study. Rhombs of hematite after siderite, and aggregates of brookite and octahedrite after ilmenite were found. An unidentified pseudomorph was found in one druse. It consists of a shell of fine granular reddish brown siderite, it is hollow inside. The shape is that of an orthorhombic or monoclinic mineral, and may be a pseudomorph of a feldspar grain.

DEUTERIC MINERALS IN THE GRANITE AWAY FROM THE PEGMATITE ZONE

A deuteric mineral was defined by Sederholm⁹ as one formed in a solid igneous rock by metasomatic changes which have taken place in direct continuation of the consolidation of the magma from which the rock crystallized. This process of mineral formation was further discussed by Kemp¹⁰ and by Colony.¹¹ The writer¹² has elsewhere described deuteric minerals in some granodiorites of Idaho, and has given criteria for their recognition. Spurr¹³ was probably one of the first in this country to recognize that many

⁹ Sederholm, J. J.; On synantetic minerals and related phenomena: *Bull. de la Commission Geologique de Finlande*, No. 48, pp. 141-142 (1916).

¹⁰ Kemp, J. F.; After effects of igneous intrusion: *Bull. Geol. Soc. Am.*, vol. 33, p. 237 (1922).

¹¹ Colony, R. J.; The final consolidation phenomena in the crystallization of igneous rocks: *Jour. Geology*, vol. 31, p. 170 (1923).

minerals which were usually considered as belonging to an early stage of magmatic crystallization, are in reality late. Bowen¹⁴ and Washington¹⁵ have further discussed this phase of the problem.

Schaller¹⁶ has studiously examined the replacement of early minerals in pegmatites by later minerals and has raised the question whether this process of replacement holds in the genesis of common igneous rocks. He asks if hydrous minerals such as the hornblendes and biotites are reaction products in an already solid igneous rock rather than original pyrogenetic minerals. This idea of the formation of these two minerals cannot be universally applied since those minerals occur as phenocrysts in lavas and tuffs which are the quenched equivalents of plutonic types. The writer believes that many pyrogenetic minerals, however, have continued growing by replacement of adjacent minerals after the rock was solid, by addition of material brought in by solutions from below.

In a recent paper Fenner¹⁷ has given a very detailed discussion of the progression of crystallization in igneous rocks and has explained the importance of volatile agents in this progression.

An excellent discussion of the changes that have gone on in igneous rocks during and following their consolidation is given by Grubenmann and Niggli.¹⁸ They divide the changes into three stages; the liquid magmatic, the pneumatolytic, and the hydrothermal. Changes of the liquid stage are the resorption or making-over of olivine, the replacement of lime-rich plagioclase by soda-rich, the change of pyroxene into hornblende, and some types of unmixing. Changes during the pneumatolytic stage: the nepheline

The magnetite iron deposits of southwestern New York: *New York State Museum Bulletin*, 249-250, p. 120 (1923).

¹² Gillson, J. L.; Granodiorites in the Pend Oreille district of northern Idaho: *Jour. Geology*, vol. 35, pp. 21-30 (1927).

¹³ Spurr, J. E.; The Ore Magmas, *New York*, vol. 1, pp. 330-331 (1923).

¹⁴ Bowen, N. L.; The order of crystallization in igneous rocks: *Jour. Geology*, vol. 20, pp. 457-468, (1912).

¹⁵ Washington, H. S.; Deccan traps and other plateau basalts: *Bull. Geol. Soc. Am.*, vol. 38, p. 765 (1922).

¹⁶ Schaller, W. T.; Genesis of lithium pegmatites: *Amer. Jour. Science* (5), vol. X, pp. 278-279 (1925).

Mineral replacements in pegmatites: *Amer. Mineral.*, vol. 12, pp. 62-63 (1927).

¹⁷ Fenner, C. N.; The Katmai magmatic province: *Jour. Geology*, vol. 34, pp. 743-760 (1926).

¹⁸ Grubenmann, U. and Niggli, P., Die Gesteinsmetamorphose, I, pp. 183-188, Berlin, 1924.

is replaced by sodalite, orthoclase by albite, scapolite is formed, and such minerals as topaz, tourmaline, fluorite, zircon, cassiterite, etc. are introduced. The enrichment of the magma in water was the principal cause of the distillation of these volatile emanations, although volatile fluorides, chlorides and boron compounds are also distilled. In the hydrothermal stage these exhalations are replaced by H_2O and CO_2 . The solutions become more dilute, the temperature has fallen and is in the range between 400° and 100° . Serpentine, talc, kaolin, pyrite, sericite, chlorite, titanite, alunite zeolites, etc., form in this final stage.

The microscopic study of the thin sections of the granite from the "Redstone Red" quarry showed that the period of mineral formation did not close with the final consolidation of the rock, and the crystallization of the last pyrogenetic mineral.

The most conspicuous example of this post-consolidation mineral formation was the albitization of the microcline. So completely was the microcline albitized that evidence of it can be seen in granite fragments with the naked eye. In thin section the albitization is shown by the pronounced development of injection perthite (Figure 3). This type of perthite is distinguished from the ordinary perthite described by Warren¹⁹ and Alling²⁰ by the following features:

1. It is not confined, as is ordinary perthite, to rudely parallel plates in the host mineral, for here the albite component is of most irregular distribution. In many crystals seen in section, one end of an original microcline grain is now entirely albite, while the other end contains little or none. The middle zone of the microcline crystal contains residual masses or islands of unreplaced microcline in a groundmass of albite. This is proof that the feature is not ordinary perthite, in which the relative proportions of the two kinds of feldspar should be about uniform throughout the crystal, and not greater than a moderate amount of one in the other. The proof of replacement of microcline by albite, if not convincing in its very appearance, is clinched by the second characteristic, seen in many grains, which is:

¹⁹ Warren, C. H.; A quantitative study of certain perthitic feldspars: *Proc. Amer. Acad. Arts and Sciences*, vol. 51, pp. 127-154 (1915).

²⁰ Alling, Harold L.; The mineralography of the feldspars: *Jour. Geology*, vol. 29, pp. 219-224 (1921); vol. 31, pp. 283-291 (1923).

The potash-soda feldspars: *Jour. Geology*, vol. 34, p. 601 (1926).

2. The albite component is in optical orientation with the outermost rim of an adjacent zoned plagioclase.

This process of albitization has been described by Brögger,²¹ Landes,²² Schaller,²³ Hess,²⁴ Colony,²⁵ Warren,²⁶ Geijer,²⁷ Grubenmann and Niggli,²⁸ and others.

The process of albitization of the feldspar in basic rocks is even better known, but it has not always been due to the introduction of soda, but rather to a breaking down of the plagioclase. It was in this sense that the term was used by Geikie.²⁹ Descriptions have been published, for example, by Becke,³⁰ Dewey and Flett,³¹ Harker,³² M'Lintock,³³ Shannon,³⁴ Fenner,³⁵ and Reynolds.³⁶

²¹ Brögger, W. C.; Die Mineralien der Syenitpegmatitgänge der sudnorwegischen Augit- und Nephelinsyenite: *Zeit. Krist.*, vol. 16, p. 559 (1890).

²² Landes, K. K.; The paragenesis of the granite pegmatites of Central Maine: *Amer. Mineral.*, vol. 10, p. 373 (1925).

²³ Schaller, W. T.; Genesis of the lithium pegmatites: *Amer. Jour. Science*, (5) vol. X, pp. 278-279 (1925).

Mineral replacement in pegmatites: *Amer. Mineral.*, vol. 12, pp. 62-63 (1927).

²⁴ Hess, F. L.; The natural history of the pegmatites: *Eng. Min. Jour.-Press*, vol. 120, p. 293 (1925).

²⁵ Colony, R. J.; The final consolidation phenomena in igneous rocks: *Jour. Geology*, vol. 31, p. 170-175 (1923).

²⁶ Warren, C. H.; Petrology of the alkaline granite and porphyries of Quincy and Blue Hills, Mass.: *Proc. Amer. Acad. Arts & Sciences*, vol. 49, p. 214 (1913).

²⁷ Geijer, Per; Reference not given, quoted by Sederholm, J. J.: *Bull. de la Commission Geologique de Finlande*, No. 48, pp. 133-134 (1916).

²⁸ Grubenmann, U. and Niggli, P.; Die Gesteinsmetamorphose, I, p. 184. Berlin, 1924.

²⁹ Geikie, A.; Textbook of Geology, London and New York, vol. 2, p. 790 (1903).

³⁰ Becke, F.; Petrographische Studien am Tonalit der Rieserferner: *Tschermaks Min., Pet. Mitt.*, vol. 13, p. 420 (1892).

³¹ Dewey, Henry and Flett, J. S.; British pillow lavas, and the rocks associated with them: *Geol. Magazine*, vol. 8, pp. 202-209; 241-248 (1911).

³² Harker, Alfred; Petrology for students, 6th Ed., London, p. 197 (1923).

³³ M'Lintock, W. F. P.; On the zeolites and associated minerals from the Tertiary lavas around Ben More, Mull: *Trans. Royal Soc. Edinburgh*, vol. 51, pp. 1-33 (1915).

³⁴ Shannon, Earl V.; The mineralogy and petrology of intrusive Triassic diabase at Goose Creek, Loudon Co., Virginia: *Proc. U. S. Nat. Museum*, vol. 66, p. 83 (1924).

³⁵ Fenner, C. N.; The Watchung basalt and the paragenesis of its zeolites and other secondary minerals: *Annals New York Acad. Science*, vol. 21, No. 2, p. 121 (1910).

³⁶ Reynolds, S. H.; Igneous rocks of the Tortworth inlier: *Quart. Jour. Geol. Soc. London*, vol. 80, p. 107 (1924).

That feldspar is deposited by solutions was long ago established by Michel Levy,³⁷ and a number of examples of the formation of secondary albite are given by Hintze.³⁸

Further evidence of post-consolidation mineral formation in the granite of the "Redstone Red" quarry is given by the biotite. Many grains of this mineral have protuberances which interlock in a complicated manner with the late albite. Several instances of graphic structures of biotite and albite were noted, while a few of biotite with fluorite were seen. The biotite could not have been entirely deuteritic, its stage of growth apparently overlapped from the pyrogenetic into the deuteritic. This observation of the form of biotite is similar to one made by Sederholm.³⁹

The association of zircon, allanite, apatite, and minute blebs of a green mineral of high refractive index, unidentified, only with the peculiar biotite-albite structures is very suggestive that these minerals formed also by late emanations since these minerals are absent from areas in the slides where injection perthite had not formed. The grouping together with them of considerable fluorite strengthens the suggestion, for fluorite in granites is certainly always a deuteritic mineral. Allanite is unusually abundant for a normal granite. The writer⁴⁰ has elsewhere noted allanite as a deuteritic mineral.

The epidotization of the granite was due to post-consolidation mineral formation, but in the "Redstone Red" quarry is not a conspicuous feature. Chloritization of the biotite, is, however, more general, and it belonged to the sequence of deuteritic mineral formation.

INTERPRETATION

The druses and cavities in the pegmatite zone have left a record of a long continued progression of solutions which passed upward through the granite after it had consolidated. These emanations followed readily through the pegmatite zone, but with more

³⁷ Levy, Michel; *Bull. Soc. Geol. France*, IX, referred to by Erdmannsdörfer, O. H., *Petrographische Untersuchungen an einigen Granit Schieferkontakten der Pyrenäen: Neues Jahrb. f. Mineralogie, etc. Beilage Band*, vol. 37, p. 763 (1914).

³⁸ Hintze, C.; *Handbuch der Mineralogie, Leipzig*, pp. 1433-1454 (1892).

³⁹ Sederholm, J. J., *op. cit.*, p. 130.

⁴⁰ Gillson, J. L.; The granodiorites of the Pend Oreille district of northern Idaho: *Jour. Geology*, vol. 35, p. 27 (1927).

difficulty they also passed through the body of the solid granite and brought about changes in its mineral composition.

The paragenesis of the minerals has left a record of the changing character of these emanations; first of high temperature and a composition rich in soda, and containing some of the rare earth elements; they were later rich in fluorine and many other elements; while still later and as the temperature fell carbonates formed.

This progress of post-consolidation mineral formation here illustrated is so similar to that described by others that it is believed that it can now be considered as one of the normal accompanying features of large scale intrusion. The effects of these emanations must be sought in the study of all intrusive rocks.

I know not what part of these emanations were volatile and what part liquid. Thus the words "pneumatolytic" and "hydrothermal" have been avoided. Deuteric minerals illustrate, however, as do the widely disseminated minerals of contact metamorphic zones, the power of these igneous emanations to pervade solid rock without visible channel or fissure, a fact to which Kemp, for example, has already called attention.⁴¹

FAMOUS MINERAL LOCALITIES: CRESTMORE, RIVERSIDE COUNTY, CALIFORNIA

ARTHUR S. EAKLE, *University of California*.

The place known as Crestmore is a suburban station situated a few miles west of Riverside, and is easily reached in a few minutes by electric train or auto. Its proximity to the city makes it one of the most convenient of collecting places, because the full day can be utilized at the quarry and even the boxing and shipment of the material can be done there.

The Riverside Portland Cement Company has its plant here, and uses both the limestone and the underlying granodiorite for its manufacture of cement. During active work with its constant blasting, a permit should be obtained to go on the floor of the quarries but this is freely given by the officials and no objection is made to the amount of material collected and shipped.

The mass of limestone appears as two contiguous hills, separated by a narrow swale, and joined by a lower ridge, and the hills rise a few hundred feet above the surrounding plain. The south hill,

⁴¹ Kemp, J. F.; The pegmatites: *Econ. Geology*, vol. 19, pp. 711-712 (1924).

locally characterized as the "Chino Hill" from its pure white crystalline limestone, presents nothing of special interest to the collector. It is a fine to coarse grained crystalline marble having few associated minerals developed within it. An occasional specimen of columnar wollastonite has been found, and at the south end of the quarry the rock grades into a dark gray brucitic limestone with much graphite. The north hill, on the contrary, contains a wonderful array of minerals formed by contact and hydrothermal metamorphism. The abundance of blue calcite in this hill gave it the distinguishing name, "Sky Blue Hill." The large "Commercial" quarry on the east side of this hill has yielded practically all the minerals listed from Crestmore. The original limestone was either highly silicious or, what seems more probable, was interbedded with sandstone, and the whole mass was metamorphosed by its contact with the granodiorite. Later intrusions of narrow dikes of monzonite, aplite and pegmatite veins, accompanied or followed by solutions, brought about a complete change in the crystallization, composition and structure. What was an original homogeneous marble, like that of the Chino Hill, became converted into areas of localized mineral associations. Deep blue calcite in large cleavage rhombohedrons was crystallized and the intermixed associated minerals were found to be constantly varying. With the stupendous blasting and rapid clean-up of the quarry floor minerals observed one day would be gone the next, and some of them never seen again. My attention was directed to the deposit by the receipt of some specimens of sky-blue calcite associated with brownish monticellite and studded thickly with green brittle plates of xanthophyllite. The material was so abundant that it was used for road-metal and for sugar refining as well as for cement, with the consequence that it soon disappeared and nothing like it has been found since. A similar case of disappearance is the new mineral, foshagite. One large and several smaller boulders were observed containing this mineral in large masses, with the white granular thaumasite; yet two months later Mr. Foshag visited the quarry and not a vestige of these boulders nor of the mineral could be found. Mineral science has been enriched by the blasting operations of the cement company but at the same time it has lost material of incalculable value to science, through the speedy destruction of the rock without any super-

vision by some one versed in the value of minerals. No other metamorphic limestone deposit is known which presents such an intricate maze of new, rare, and unusual associations, all of specimen value.

At the present time the company has transferred its operations to another deposit a few miles west of Crestmore and the "Commercial" quarry has been abandoned. This does not mean that it lacks interest to the collector. Vesuvianite, garnet, wollastonite, gehlenite, sky-blue calcite, crestmoreite are some of the minerals still to be found in abundance, and there is always the joyful anticipation of finding new species while knocking about amongst the numerous boulders, discarded for cement.

Mineralogists visiting southern California should plan to stop at Riverside, and equipped with bag, hammer and lunch, should spend at least one day at the quarry. Specimens worth while can be collected and there is still much unrecognizable material to unravel. Danburite has not been reported from the quarry but Mr. Vonsen found it in his samples. The metallic sulphides are subordinate in amount yet some good specimens of them have been found.

For the convenience of those who might visit the quarry a complete list of the minerals so far observed at Crestmore is given below. Those which were new minerals when described have been starred.

Anglesite, apatite, apophyllite, aragonite, arsenopyrite, augite, axinite, azurite, biotite, bornite, brucite, calcite, cerussite, chalcocite, chalcopyrite, chondrodite, clinocllore, crestmoreite,* danburite, datolite, diopside, epidote, foshagite,* galenite, garnet, gehlenite, graphite, greenockite, hematite, hornblende, hydromagnesite, jurupaite,* kaolinite, labradorite, laumontite, limonite, malachite, merwinite,* monticellite, muscovite, okenite, opal, orthoclase, periclase, phlogopite, plazolite,* prehnite, pyrite, quartz, riversideite,* scapolite, serpentine, sphalerite, spurrite, tetrahedrite, thaumasite, titanite, tourmaline, tremolite, vesuvianite, wilkeite,* wollastonite, xanthophyllite and zircon.

PROCEEDINGS OF SOCIETIES
NEW YORK MINERALOGICAL CLUB*Annual Meeting of April 20, 1927*

The Forty-first Annual Meeting of the New York Mineralogical Club was held in the East Assembly Room of the American Museum of Natural History on the evening of April 20, at 8:15 P.M. The President, Dr. Paul F. Kerr, presided and there was an attendance of 22 of whom 18 were members.

The following officers were elected for 1927-28:

President: Paul F. Kerr.

First Vice-President: George E. Ashby.

Second Vice-President: Frederick I. Allen.

Secretary: Herbert P. Whitlock.

Treasurer: Gilman S. Stanton.

Proceeding to the paper announced for the evening, Mr. Donald H. Selchow gave a highly interesting account of "Mineral collecting in the vicinity of Lead, South Dakota." The speaker had gained considerable intimate knowledge regarding his subject through the experience of working for several weeks in the Homestake Gold Mine. He described this property, and also the Tungsten Mine at Lee, in the Central Black Hills. Speaking of the latter he described the wolframite and scheelite, which constitute the ore minerals as occurring in dolomite; the wolframite in a granular condition and in bladed crystals, and the scheelite in stringers and in crystals in vugs. As accessory minerals he mentioned jarosite in hexagonal plates, gypsum, barite, hematite, limonite and possibly plumbojarosite. Analyses show 3% WO_3 and \$4.00 in gold per ton.

Summarizing the minerals of the Homestake mine, Mr. Selchow cited cummingtonite as the predominating mineral; also arsenopyrite in good crystals, pyrrhotite and pyrite in stringers, and calcite and fluorite in veins throughout the ore body. Siderite is relatively rare and free gold in recognizable specimens even more so. A number of excellent slides illustrated Mr. Selchow's address, at the close of which a vote of thanks was tendered to him for his interesting and valuable paper.

Among occurrences of recent interest, Mr. Whitlock showed the chrysotile asbestos from 81st Street and Eight Avenue, Manhattan, and some chabazite (pharcolite) from the hiddenite locality in North Carolina. Mr. Morton described the anhydrite from Prospect Park, Paterson, N. J. Miss Schroder showed some fine sphalerite from British Columbia, also some placer copper and silver specimens.

HERBERT P. WHITLOCK, *Secretary*

Regular Monthly Meeting of May 18, 1927

A regular monthly meeting of the New York Mineralogical Club was held in the East Assembly Room of the American Museum of Natural History on the evening of May 18, at 8:15 P.M. The President, Dr. Paul F. Kerr, presided and there was an attendance of 30 members.

Mr. Samuel G. Gordon addressed the Club on "The Minerals of Pennsylvania." Mr. Gordon touched on the geology and physiography of Pennsylvania, and outlined several collecting trips to include several of the principal localities starting

from Philadelphia. He mentioned Lafayette, Phoenixville, the falls of French Creek, Friedensville, Cornwall, Avondale and several other notable localities. The speaker made use of a number of excellent lantern slides, depicting both the quarries and mines touched upon and some of the specimens obtained in the past from them. At the close of this paper, a vote of thanks was tendered to the speaker for his interesting address.

HERBERT P. WHITLOCK, *Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, May 5, 1927

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the President, Mr. Vaux, in the chair. Twenty-five members and eleven visitors were present.

Mr. Paul L. Storm addressed the Society on "Prehistoric Flint Mining." The methods of ancient flint mining and the development of the technique in chipping flint was traced from the early paleolithic to the bronze age. The flint mines at Grimes Graves, England, Spiennes, Belgium and Champignolles, France, were described in detail. The address was illustrated by lantern slides showing diagrams and pictures of the mines and mining tools used. Specimens of flint implements from various periods of the stone age were exhibited.

Mr. Biernbaum described a trip taken by five members of the Society to Moore's Station, N. J., where in the workhouse quarry splendid microscopic epidote was found. Mr. Cienkowski reported on a trip to Branchville, Conn., Brewster, N. Y. and Paterson, N. J. Pink spodumene and beryl were found at Branchville.

F. A. CAJORI, *Secretary*

Academy of Natural Sciences of Philadelphia, June 2, 1927

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with an attendance of thirty members and seven visitors. The president, Mr. Vaux, presided.

Mr. R. E. Hellmer was elected to membership.

Mr. S. G. Gordon addressed the society on "A mineralogical trip abroad." The speaker described the Jubilee meeting of the Mineralogical Society in London last September and the European collections which he visited afterwards. Among these were the Danish collections at Copenhagen which are rich in minerals from Greenland, Iceland and Norway; the Natural History Museum collection, in Berlin; the Baldauf private collection in Dresden; the School of Mines collection in Freiberg; collections at Munich, Berne, Geneva, Vienna and Budapest, the latter being especially fine. The speaker also described the laboratory and work of Dr. Victor Goldschmidt and his pupils in Heidelberg where he spent several months.

Mr. Biernbaum described the Club trip over Memorial Day to Conowingo where along the re-location of the Pennsylvania Railroad, gypsum, allophane, titanite, pyrite and clinozoisite were found.

F. A. CAJORI, *Secretary*

REVIEWS

REVIEW OF A RECENT ARTICLE ON THE SYMMETRY OF THE ETCH
FIGURES OF ALKALI HALIDES

Pointing out that the study of alkali halides by X-rays indicates their structure to be holosymmetric, while the etch-figures of some of them are recorded to be gyroïdal or plagihedral, A. Hettich, a student under Fajans and Herzfeld at Munich, has recently published the results of a somewhat elaborate investigation on the influence of various substances on the symmetry of these etch-figures.¹ Most of his observations were made on pure potassium chloride, fused to destroy organic matter, and then cleaved into small blocks or plates. When these blocks were etched with nearly saturated solutions of KCl, for periods of a few minutes or hours, series of tiny pyramids appeared on the surfaces, and their symmetry could be readily recognized with a low power microscope. Upon taking special precautions to exclude organic matter, such as doubly distilling the water over permanganate, cleaning all vessels with bichromate-sulfuric acid mixture, heating the forceps used to handle the crystals in a flame, and excluding dust as far as practicable, the etch-figures were found to be entirely symmetrical. However, when dust was admitted, when the crystals were handled, or when the water was stirred with animal charcoal, filter paper, etc., the etch-figures always showed a certain amount of rotation with respect to the crystal axes, corresponding to plagihedral (gyroïdal) symmetry. The sense of this rotation is always clockwise. When minute amounts of optically active organic compounds were added to the etching solution, the same rotation was produced in some cases, although most of the substances tried showed no effect. Of the substances, both optical isomers of which could be used, only lactic acid had a consistent asymmetric effect, but both right and left forms produced the same etch-figures. The author concludes that the merosymmetry (he uses the less apt term hemihedrism) shown by the etch figures of potassium chloride, potassium bromide, (which was also tried to some extent), and presumably the rest of the alkali halides, is due to a trace of optically active organic matter contaminating the etching solution and being differentially adsorbed on the surface of the crystal.

The question of the cause of this apparent merosymmetry of the alkali halides, or indeed, of the whole problem of amphisymmetry, is a very interesting one, but the reviewer can not feel that it has been adequately handled by this author. For one thing, he does not seem very familiar with crystallographic literature, for he innocently asks "whether perhaps further cases of such pseudoplagihedrism may not be found outside of the alkali halide group?" Several years ago, in a paper on amphisymmetric crystals, which Hettich has overlooked, the reviewer pointed out that the literature contained over a hundred instances of this relation, all of the crystal systems being represented.² Then, his deductions from the observational data do not seem very sound.

In the first place, the obtaining of symmetrical etch figures in the uncontaminated experiments would not demonstrate that the substance is holosymmetric unless it were shown that the general form (hkl) was actually present as a bounding

¹ *Z. Krist.*, 64, 265-295 (1926). Abstracts of the same work have been also published elsewhere.

² *Am. J. Sci.*, 4, 237-244 (1922). An amphisymmetric crystal is defined as one which shows different symmetry when examined by different methods.

face on those figures, and this was not done. In the second place it has not been proved that the merosymmetry observed, when contamination occurred, was actually due to an optically active constituent in the dust or other contaminating agent. Such experiments as were tried with optically active compounds were admittedly inconclusive, and the fact that the revolution of the etch-figures was clockwise in all cases, even when two optical isomers of a given compound were used, seems to the reviewer to indicate quite clearly that the production of gyroidally arranged etch-figures is a property characteristic of the crystal itself. All that Hettich does appear to have demonstrated is that a trace of organic matter in the etching solution leads to the development on the etch figures of an (hkl) form, which, for some reason as yet undetermined, has a clockwise gyroidal face-arrangement.

This review is written in the hope that someone may be encouraged to carry on further work on the alkali halides, and clear up the points still in question. Perhaps instead of etching crystal surfaces it would be more informing to grow crystals under conditions leading to the development of (hkl) faces, along lines such as those so well worked out by Walcott in this journal recently.³ The lack of rotation of the plane of polarized light showed long ago that the alkali halides are structurally holosymmetric, and the reviewer quite agrees with the author's criticism of the theory of Johnsen and of Thirring, that the ions in the crystal are nevertheless themselves plagihedral. Etch figures bring out only surface, not internal, relationships. However, as has been stated elsewhere⁴ the phenomena of amphisymmetry do make it appear that even though the ions in a crystal may be arranged with a high degree of symmetry, under certain conditions at the instant of solution or deposition a diminished symmetry, perhaps characterizing the atoms rather than the ions, can assert itself. Possibly Hettich's contaminating organic matter merely represses ionization at some critical moment in the change from liquid to solid phase (or the reverse); or, it may slow up, differentially, the rate of change of the two opposing ions. However, theoretical speculation is of little value until the necessary experimental data are available. A crystallographic problem of considerable interest and probable importance awaits further investigation.

E. T. W.

NEW MINERAL NAMES

Heterobrochantite

H. BUTTGENBACH: L'Hétérobrochantite, variété d'antlerite (Stelznérite). *Bull. Ann. Soc. Geol. Belg.*, 49, pp. 3-11 (1926).

NAME: Named in allusion to its *heteropolar* (*hemimorphic*) development and its resemblance to *brochantite*.

CHEMICAL PROPERTIES: A basic sulfate of copper. Formula: Like that of antlerite, $3\text{CuO} \cdot \text{SO}_3 \cdot \text{H}_2\text{O}$. Analysis: CuO 68.03, SO_3 22.33, H_2O 10.53, Insol. 0.01; Sum 100.93.

CRYSTALLOGRAPHIC PROPERTIES: Orthorhombic. Habit flat plates. Cleavage (100) good, also (010). Under the microscope the crystals appear to be hemimorphic, one set of faces making an angle of 45° with the vertical, the opposite set 54° .

³ *Am. Mineral.*, 11, 221-239, 259-278 (1926).

⁴ *Am. J. Sci.*, 4, 241-242 (1922); also *Am. Mineral.*, 9, 53-54 (1924).

PHYSICAL AND OPTICAL PROPERTIES: Color green, colorless when very thin, not pleochroic. Biaxial positive. Plane of the optic axes parallel to (100), acute bisectrix parallel to (100). $\alpha=1.743$, $\gamma=1.776$. Birefringence 0.033 (measured).

OCCURRENCE: As a green microcrystalline mass from Chile.

DISCUSSION: While the chemical composition of the heterobrochantite and of antlerite are the same the author believes there are sufficient optical differences to distinguish them; the indices are somewhat different, the plane of the optic axes in heterobrochantite is parallel to (100), in antlerite parallel to (001), the acute bisectrix in heterobrochantite is normal to (001), in antlerite it is normal to (010).

W. F. FOSHAG

Kipushite

H. BUTTGENBACH: Description d'un Mineral du Katanga. (Description of a mineral from Katanga). *Acad. Roy. Belg. Bull. Classe Sciences*, pp. 905-913 (1926).

NAME: From the locality *Kipushi*, Katanga.

CHEMICAL PROPERTIES: A hydrous phosphate of zinc and copper. Formula: $6(\text{Cu}, \text{Zn})\text{O} \cdot \text{P}_2\text{O}_5 \cdot 6\text{H}_2\text{O}$. Analysis (by M. Bolsius) CuO 35.99, ZnO 28.94, P_2O_5 19.90, H_2O 14.31, SiO_2 0.65. Sum 99.79. Soluble in acids.

CRYSTALLOGRAPHIC PROPERTIES: Monoclinic. $a:b:c=0.9540:1:0.7397$. $\beta=77^\circ 6\frac{1}{2}'$. Forms (110), (111), ($\bar{1}11$), (421). Habit pyramidal. Cleavage ($\bar{1}11$).

PHYSICAL AND OPTICAL PROPERTIES: Color deep blue, streak green. Luster vitreous. Not pleochroic. Biaxial, positive. Indices of refraction between 1.63 and 1.74. Birefringence .025. Plane of the optic axes parallel to (010). $Bx_a \wedge c = 96^\circ 30'$.

OCCURRENCE: Found in the Prince Leopold mine at Kipushi, Katanga, Belgian Congo, in crystals averaging 3-5 mm. in size with aurichalcite on calamine.

DISCUSSION: Kipushite is the same as the unknown mineral described by Mennell and Spencer (*Mineralog. Mag.*, XIX, No. 90, pp. 69-72, 1920) and belongs to an isomorphous series with vezelyite and barthite, kipushite being the phosphate end member, barthite the arsenate end member and vezelyite the intermediate member.

W.F.F.

Ternovskite

I. POLOVINSKINA: *Mem. Soc. Russ. de Min.* 2nd Ser., 54, pp. 142-234 (1925).

NAME: From the locality, *Ternovsky* Mine, Russia.

CHEMICAL PROPERTIES: An alkalic hornblende. Analysis: (by Mrs. E. A. Sverginisky) SiO_2 52.72, TiO_2 0.31, Al_2O_3 3.65, Fe_2O_3 15.46, FeO 8.16, MgO 9.16, CaO 2.10, Na_2O 5.91, K_2O 0.68, ign. 1.85.

PHYSICAL AND OPTICAL PROPERTIES: Biaxial. Plane of the optic axes parallel to (010). Extinction angle $Z \wedge (001) = 27^\circ - 35^\circ$. $\alpha=1.655$, $\beta=1.664$, $\gamma=1.668$. Birefringence .013. Dispersion $\rho < \nu$. Pleochroism strong. X=pale bluish green, Y=pale violet, Z=pale yellow.

OCCURRENCE: Found in slate at the quarry of the Ternovsky Mine (iron) Krivoy-Rog, Kherson, Russia.

DISCUSSION: Related to rhodusite, abriachanite, crocidolite and glaucophane. The rocks of the Krivoy-Rog iron ore district are described by E. V. Tarasenko: *Acto Universitates Joronegiensis, Voronezh.* 1, 265-289, 1925.

W.F.F.